Lake Trout Studies Clearwater Bay Lake of the Woods 1984-1987

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Executive Summary

Studies to assess the current status of lake trout populations in Clearwater - Cul de Sac - Echo Bay areas of Lake of the Woods were conducted during 1984 - 87. These included a water quality monitoring program, lake trout spawning habitat/population assessment, and winter creel surveys.

Data would suggest that a decline in water quality in Clearwater - Echo Bays has occurred but comparable background information is lacking. Both chlorophyll a (1.6 - 2.3 µg/l) and total phosphorus levels (0.018 - 0.027 mg/l) indicated a higher range of productivity than is present in most oligotrophic, lake trout waters. Although a large capacity of optimum lake trout habitat remained, substantial reductions in hypolimnetic oxygen occurred in late summer.

Spawning habitat used by lake trout in Clearwater Bay was limited to a small number of sites which remained clean of algae and sediment. Several shoals, which had been used by spawning trout in the 1970s, have been lost due to an increased covering of algae and to sedimentation from shoreline development.

A limited number of spawning lake trout were observed on the grounds during 1984 and 1985. The majority of fish in both years were between 60 - 80 cm (F.L.) and 6 - 14 years old. The youngest mature male and female trout were 6 years of age.

Age interpretations from pectoral fin rays consistently underestimated ages for all size ranges (>30 cm. F.L.) of Clearwater Bay trout when compared to otoliths. Annuli were more easily distinguished on lake trout otoliths. Growth of lake trout in Clearwater Bay, based on otolith ages, was

rapid and was considerably greater than the provincial average for this species. Fast growth can be attributed to the higher productivity of this area than is typical of other lake trout waters and to reductions in stock density resulting from increased angling pressure. Ages at first maturity for Clearwater Bay trout of 6 - 7 years for males and 6 - 10 years for females are characteristic of most Ontario populations.

The lake trout fishery in Clearwater Bay exhibits signs of stress from overexploitation, primarily from winter angling. Both angling effort and harvest have grown from being virtually non-existent in the late 1970s to estimates of 15,500 man-hours of effort and 2400 kg of lake trout harvested in 1987. Current harvests equal yields of 0.78 and 1.04 $kg \cdot ha^{-1} \cdot yr^{-1}$ during 1986 and 1987, respectively. The estimated catch in 1987 represents an overharvest of 109% above the recommended allowable yield for lake trout in Clearwater Bay. Although winter angling CUE's were low overall (e.g. 0.042 fish and 0.125 kg/man-hour), catch-per-unit-efforts as high as 0.366 - 0.436 kg/man-hour were observed at the opening of the angling season in early January. Anglers had taken over 83 % and 90% of the total estimated trout harvest in 1986 and 1987, respectively, by the third week of January. Expansion of the winter fishery has been paralleled by a steady decline in the catch-per-unit-effort (kg/man-hour) and significant decreases in the mean age, size and the percentage of mature trout in the angling catch. There has been an increase in the participation of non-residents from Manitoba and the United States, who now make up more than half of all winter anglers. Although anglers continue to be drawn to this area by its easy accessibility and its reputation for trophy sized lake trout, the quality of this fishery has declined.

Continued overexploitation and deterioration of lake

trout habitat in Clearwater Bay will likely result in the loss of this naturally reproducing population.

TABLE OF CONTENTS

	PAGE
Executive Summary	
Table of Contents	i
List of Tables	iii
List of Figures	iv
List of Appendices	vi
Introduction	1
A) Water quality assessment	3
Methods	3
Results and Discussion	5
B) Spawning habitat and population assessment	9
Methods	9
Results and Discussion	10
i) Spawning ground assessment	10
ii) Spawning populations	11
iii) Age, size, and sex compositions	12
C) Winter creel surveys	15
Methods	16
Results and Discussion	18
i) Effort	18
ii) Harvest	18
iii) Catch-per-unit-effort	21
iv) Age and size compositions of the catch	23
v) Residency of anglers	23
vi) Tag returns	27
D) Growth and maturity regimes	29
Methods	29
Results and Discussion	30
i) Aging analysis	30
ii) Growth	30
iii) Maturity regimes	34

TABLE OF CONTENTS

	PAGE
Management Implications	35
i) Habitat	35
ii) Harvest	37
Acknowledgements	39
Literature cited	40
Appendices	43

LIST OF TABLES

TABLE		PAGE
1	A comparison of mean water chemistry data for Stations # 1 (Clearwater Bay - East), # 2 (Deception Bay), # 3, (Clearwater Bay - West), and #4 (Echo Bay) on Lake of the Woods, collected monthly during May - November, 1984.	6
2	Secchi disc depth and chlorophyll a data for four stations on Lake of the Woods collected during May, June, July, August, September and November, 1984.	7
3	A comparison of mean fork lengths (cm), weights (kg), and age (yrs.) by sex for lake trout caught on spawning shoals in Clearwater Bay, Lake of the Woods during October 1984 and 1985. The numbers of fish in the samples are given in parenthesis.	14
4	A comparison of estimated angling effort (man-hours) and harvest (kg) of lake trout on Clearwater Bay, Lake of the Woods during January - March in 1982, 1986, and 1987.	20
5	Mean fork length (cm), mean weight (kg), and state of maturity by age (based on otoliths) of lake trout sampled from winter angling and index netting catches from Clearwater Bay, Lake of the Woods, Ontario, 1984 - 87.	33

LIST OF FIGURES

FIGURES	DESCRIPTION	PAGE
1	Location of the Clearwater Bay study area on Lake of the Woods.	2
2	Location of water quality stations and lake trout spawning grounds which were assessed during 1984 - 85 in the Clearwater - Cul de Sac - Echo Bay area, Lake of the Woods.	4
3	Histograms of available cold water fish habitat at various stations in the Clearwater - Echo Bay area of Lake of the Woods, Ontario during May - November, 1984.	8
4	Comparisons of length-frequency (fork) and age-frequency distributions for lake trout caught in experimental gill nets set on spawning grounds in Clearwater Bay, Lake of the Woods, Ontario, during October 1984 and 1985.	13
5	A comparison of effort (man-hours) and harvest (kg) of lake trout by the winter angling fishery on Clearwater Bay, Lake of the Woods during January 1 - March 31 in 1982, 1986 and 1987.	19
6	A comparison of catch-per-unit-efforts ($kg \cdot man\text{-}hour^{-1}$) and average weight (kg) of lake trout caught by anglers in Clearwater Bay, Lake of the Woods, during January 1 - March 31 in 1982, 1986, and 1987.	22
7	Length-frequency distributions for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986, and 1987 from Clearwater Bay, Lake of the Woods, Ontario.	24

LIST OF FIGURES

FIGURES	DESCRIPTION	PAGE
8	Weight class distributions (kg) for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986 and 1987 from Clearwater Bay, Lake of the Woods, Ontario.	25
9	A comparison of age-frequency distributions (based on otolith age interpretations) for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986 and 1987 from Clearwater Bay, Lake of the Woods, Ontario.	26
10	Residency of anglers contacted on Clearwater Bay, Lake of the Woods, during January 1 - March 31, in 1982, 1986, and 1987.	28
11	A comparison of ages interpreted from pectoral fin rays vs. otoliths from lake trout caught in Clearwater Bay, Lake of the Woods during 1984-87. Numbers indicate sample sizes.	31
12	A comparison of mean fork lengths-at-age for Clearwater Bay lake trout with the provincial growth averages for this species (OMNR 1983). Ages for Clearwater Bay trout were assessed from otoliths while the provincial averages were derived from scale interpretations. Numbers indicate the sample sizes used in calculation. Horizontal bars represent the minimum and maximum lengths of fish observed in each age class.	32

LIST OF APPENDICES

APPENDIX		PAGE
1	Diagram of an egg deposition tray.	43
2	Angling activity curves for both non-workdays and workdays from Clearwater Bay, Lake of the Woods during January - March in 1982, 1986, and 1987.	44

Introduction

Lake trout (*Salvelinus namaycush*) are currently resident in the Clearwater - Cul de Sac - Echo Bay areas within the North Sector of Lake of the Woods (Fig. 1). These populations have come under increasing harvest pressure from a growing winter angling fishery. Also, continuing cottage and shoreline development on surrounding mainland and islands are suspect in the gradual deterioration of water quality and the loss of trout habitat in this area. Intensive studies to address these concerns were initiated during the 1984-85 North/Central Sector monitoring program. These included: a water quality monitoring program in co-operation with the Ministry of Environment during open water in 1984; lake trout spawning habitat and population assessment during the summer and fall of 1984 and 1985; and creel surveys of the winter angling fishery during 1986 and 1987.

Fig. 1. Location of the Clearwater Bay study area on Lake of the Woods.

A) Water quality assessment

Methods: Standard methods for the collection of water chemistry and chlorophyll a samples, and the determination of physical parameters were followed (Water Quality Branch, Environment Canada 1979).

Four water quality stations were established within the deepest basin areas (Fig. 2): Clearwater Bay - East (Station #1); Deception Bay (#2); Clearwater Bay - West (#3); and Echo Bay (#4). Both water samples and temperature/oxygen profiles were taken at each of these stations monthly from mid-May, following spring turnover, until early November after fall turnover.

Duplicate one-litre water samples were collected at one metre off the bottom and one metre below the surface for water chemistry analysis. A one-litre composite sample for chlorophyll a analysis was taken from the euphotic zone (2.5 times the Secchi depth) at each station and immediately preserved using a standard $MgCO_3$ solution. Temperature/dissolved oxygen profiles of the water column at each station were determined at 1 m intervals from surface to bottom using a Yellow Springs Instrument Model #57 dissolved oxygen metre. Instrument readings were checked against dissolved oxygen concentrations, as determined by Winkler titration (Environment Canada 1979), of water samples taken at corresponding depths at each site.

Water chemistry and chlorophyll a samples were kept cold and shipped immediately after sampling to the regional Ministry of Environment lab in Thunder Bay for analysis.

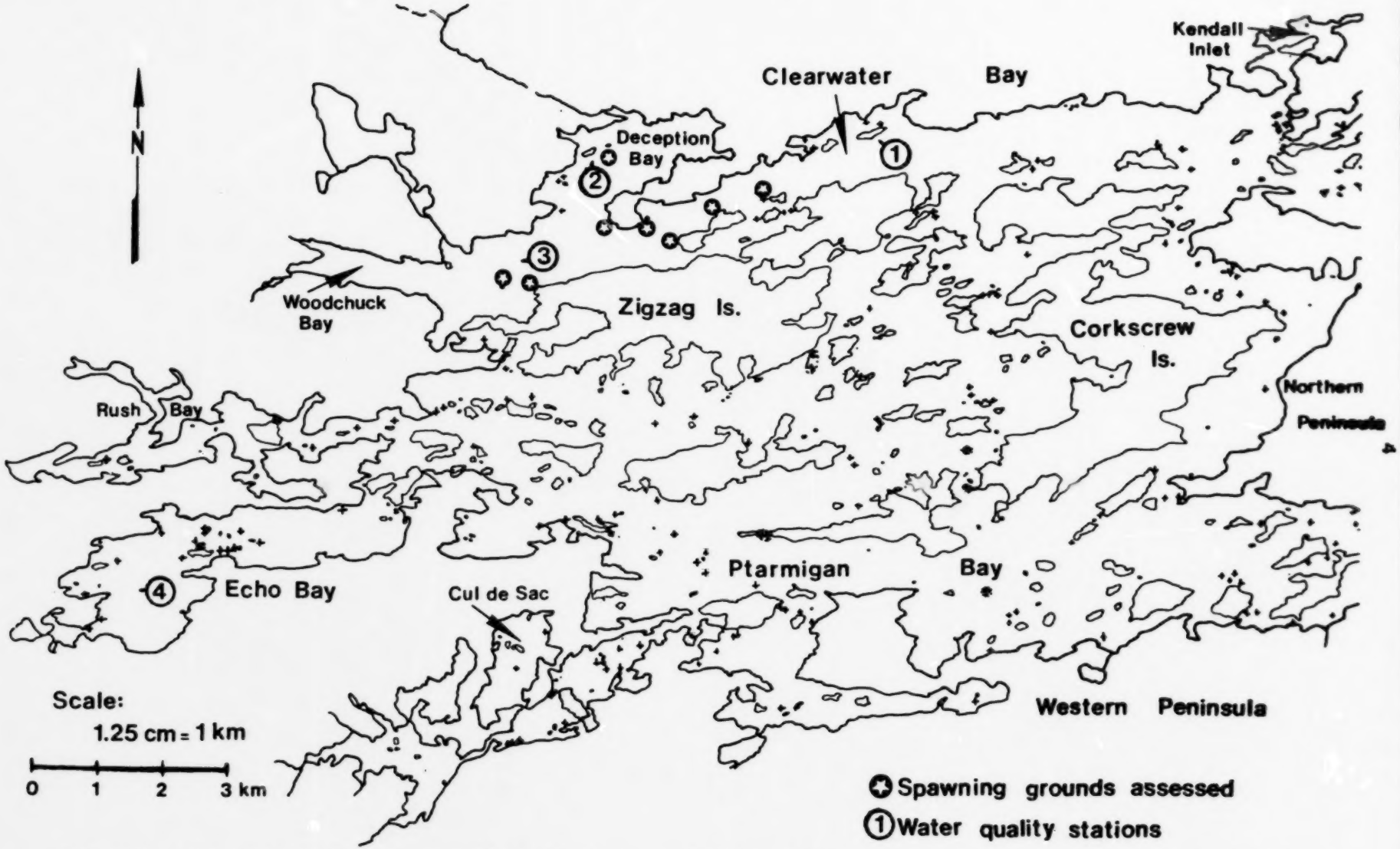


Fig. 2. Location of water quality stations and lake trout spawning grounds which were assessed during 1984 - 85 in the Clearwater - Cul de Sac - Echo Bay area, Lake of the Woods, Ontario.

Results and Discussion: Major water chemistry parameters for most stations were similar (Table 1) with the exception of slightly higher alkalinity and conductivity readings from Echo Bay (Station #4). Mean total phosphorus levels ranged from 0.018 mg/l to 0.027 mg/l while mean chlorophyll a levels ranged from 1.6 µg/l to 2.3 µg/l (Table 2) at the various stations. Mean total phosphorus levels were nearly twice those found in a subset of 225 surveyed lake trout lakes in Ontario (Beggs et al. 1985). Mean chlorophyll a levels from this area indicate a slightly higher level of productivity than is typical of lake trout waters (D. Hollinger, Ministry of Environment, Thunder Bay).

With the exception of Clearwater Bay West (Station #3), all other basins mixed completely during spring turnover. There was a reduction in hypolimnetic oxygen during August and September at all stations (Fig. 3) but it was most noticeable at Station # 1, located on Clearwater Bay East. Given that optimum coldwater fish habitat has been characterized by water temperatures of less than 10° C and a dissolved oxygen content of greater than 5 mg/l (Environmental Protection Agency 1973), optimum lake trout habitat at this site was reduced to 11 m by August and 6 m by September. All other sites exhibited a large capacity of optimum habitat capable of supporting lake trout during the entire study.

Since there was little previous physical or chemical water quality data available for these basins, it was suggested that the 1984 survey serve as a baseline for a comparative study in 5 years time (D. Hollinger, Ministry of the Environment, pers. comm.).

Table 1. A comparison of mean water chemistry data for Stations # 1 (Clearwater Bay - East), # 2 (Deception Bay), # 3, (Clearwater Bay - West), and #4 (Echo Bay) on Lake of the Woods, collected monthly during May - November, 1984.

	Station 1		Station 2		Station 3		Station 4	
Parameter	Top[2]	Bottom[3]	Top	Bottom	Top	Bottom	Top	Bottom
pH	8.100	7.500	8.000	7.400	7.900	7.400	8.000	7.500
Alkalinity	50.000	50.000	50.000	50.000	50.000	50.000	53.000	53.000
Conductivity	125.000	124.000	122.000	124.000	123.000	124.000	127.000	130.000
Hardness	58.000	57.000	58.000	58.000	58.000	58.000	60.000	61.000
Colour (Hazen Units)	15.000	16.000	16.000	16.000	15.000	20.000	13.000	17.000
Turbitity (F.T.U.)	0.740	1.300	0.630	0.980	0.670	1.300	0.650	0.980
Total P	0.014	0.028	0.016	0.020	0.017	0.037	0.015	0.032
Sol. P	0.003	0.014	0.003	0.010	0.003	0.018	0.002	0.014
No_2	<0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001
No_3	0.020	0.080	0.020	0.060	0.020	0.012	0.020	0.100
NH_3	0.010	<0.010	0.010	<0.010	<0.010	0.010	<0.010	0.010
Total kjeld. N	0.420	0.390	0.440	0.370	0.420	0.400	0.420	0.430
Suspended Solids	1.000	3.000	2.000	2.000	1.000	2.500	1.000	3.000
Dissolved Solids	87.000	91.000	84.000	90.000	76.000	91.000	95.000	82.000
Total Solids	88.000	94.000	86.000	92.000	77.000	93.000	96.000	85.000
SO_4	4.900	4.960	4.890	4.980	4.870	4.970	4.900	5.070
Si (Glass Bottle)	0.700	1.200	0.800	1.100	0.700	1.400	0.900	1.300
Ca	15.000	15.000	15.000	16.000	15.000	16.000	16.000	16.000
Mg	4.800	4.800	4.700	4.700	4.700	4.700	4.900	4.900
K	1.200	1.200	1.200	1.200	1.200	1.200	1.100	1.200
Na	2.500	2.500	2.500	2.600	2.600	2.600	2.500	2.500

1 All analyses except pH are reported in mg/l unless otherwise stated.
2 1.0 m below surface
3 1.0 m above bottom

Table 2. Secchi disc depth and chlorophyll a data for four stations on Lake of the Woods collected during May, June, July, August, September and November, 1984.

Date	Station 1		Station 2		Station 3		Station 4	
	Secchi depth (m)	Chlorophyll a (µg/l)	Secchi depth (m)	Chlorophyll a (µg/l)	Secchi depth (m)	Chlorophyll a (µg/l)	Secchi depth (m)	Chlorophyll a (µg/l)
May	3.7	2.0	3.8	2.4	3.5	3.5	4.5	1.0
June	4.2	N.A.*	4.0	2.5	4.5	N.A.	5.2	1.6
July	4.8	2.1	5.0	2.1	5.4	2.3	5.7	1.4
August	5.0	2.1	5.3	2.0	4.8	2.3	4.8	2.5
September	3.5	N.A.	3.8	N.A.	3.8	N.A.	3.6	N.A.
November	4.0	1.5	4.3	1.1	4.8	1.2	4.3	1.4

* Data not available

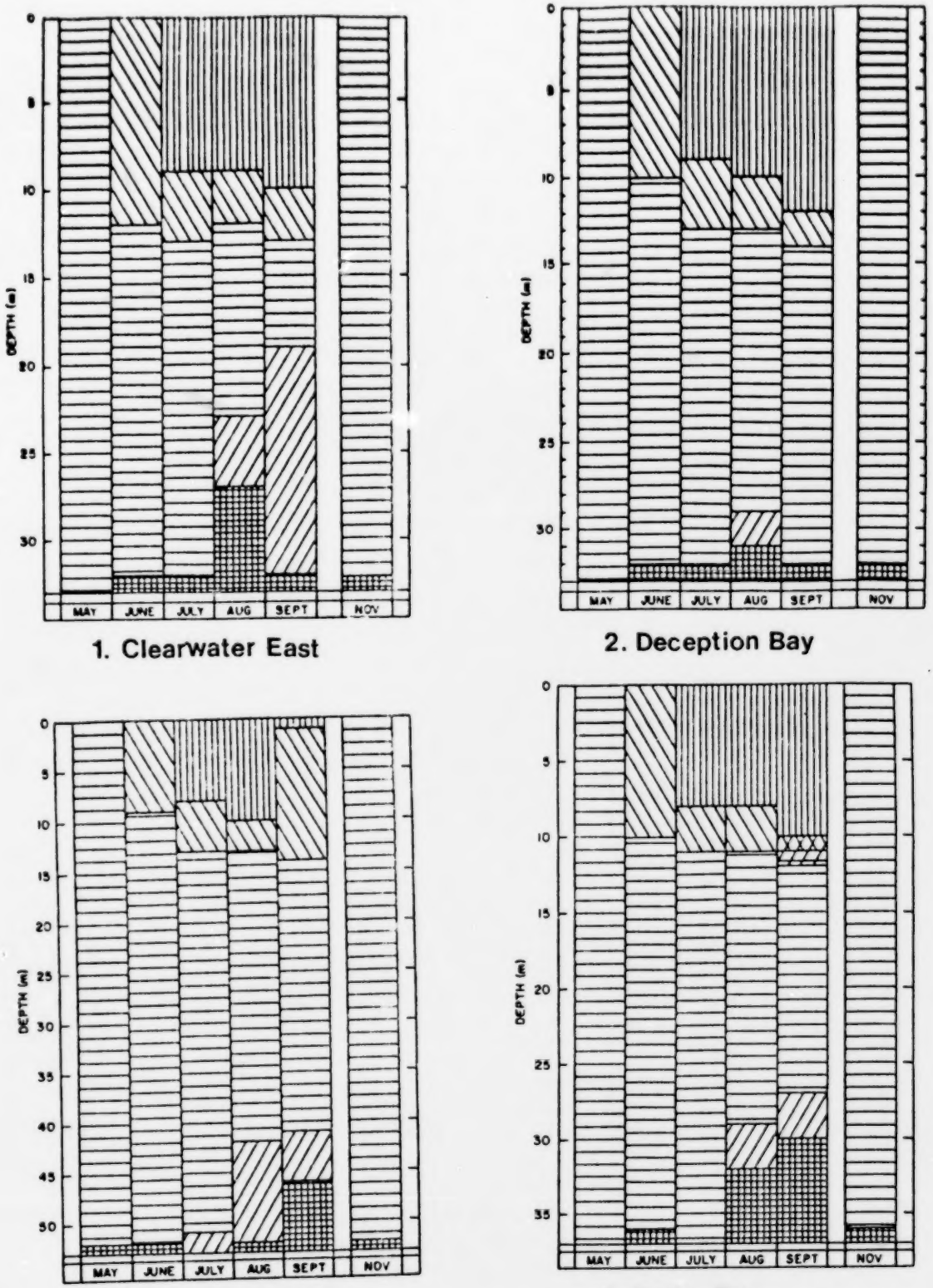


Fig. 3. Histograms of available cold water fish habitat at various stations in the Clearwater - Echo Bay area of Lake of the Woods, Ontario during May - November, 1984.

B) Spawning habitat and population assessment

Methods: Potential lake trout spawning areas were located during preliminary surveys of the shoreline around the western end of Clearwater Bay (Fig. 2) in August 1984. Areas were assessed visually, both from a boat and underwater.

Multifilament gillnets, each measuring 30.3 m in length, 1.8 m in depth, and fitted with small-sized mesh of 3.8, 5.1, and 6.4 cm stretched, were fished nightly at selected locations around Clearwater Bay West from October 1 - 25, 1984 and from October 1 - 18, in 1985. Nets were positioned parallel to shorelines along suspected lake trout spawning areas in about 1.8 - 2.5 m of water. They were set just prior to dusk (18:30 - 19:00) and usually fished until midnight. By running the boat along parallel to submerged nets and using a 12 volt hand-held spotlight, entangled fish were easily observed. In most cases, fish were caught only by their teeth or maxillary bones and could be easily extracted without having to lift the entire gill net.

All captured trout were immediately measured for length/weight and sexed by extruded gonadal products. Both scales and a marginal pectoral fin ray were collected for aging purposes. The right marginal pectoral fin ray was removed in 1984 and the left ray in 1985. All fish were also tagged with numbered yellow plastic disc tags. These were affixed with 4.5 kg monofilament fishing line on the posterior margin of the left gill cover in 1984 and in front of the dorsal fin, anchored beneath the anterior pterygiophores, in 1985. With the exception of one fish which was retained for detailed aging analysis in 1985, all trout were released alive.

Fish were aged from thin cross-sections (0.25 - 0.30 mm thickness) cut from the proximal end of the marginal pectoral fin rays. The rays were mounted in an epoxy matrix and sectioned using a diamond wafering saw. Sections were then viewed through a binocular microscope using transmitted light.

The stomachs of all other species, caught in gill nets, were examined in detail for the presence of ingested trout eggs.

Egg trays (Appendix 1), measuring one square foot in area and constructed of nylon window screening backed by one-quarter inch galvanized mesh (M. Gaboury, Manitoba Department of Natural Resources, pers. comm.), were placed on the spawning grounds at sites # 1 and # 3A in 1985 to verify the deposition of viable trout eggs at these locations. Trays were set on the substrate and covered with rock rubble on October 4, at the start of the spawning season, and examined on October 21 following its completion.

Results and Discussion:

i) Spawning ground assessment: Of the eight locations which were investigated (Fig. 2), five were judged to have the greatest potential for lake trout spawning and subsequent assessment. These appeared to fulfill known lake trout spawning habitat requirements (Martin and Olver 1980; V. Macins, pers. comm.) which include: location along a shoreline or offshore shoal area which is adjacent to deep water and exposed to prevailing westerly winds; a hard substrate in 0.5 - 3 metres of water, composed of large boulders and rock rubble (3 - 15 cm in diameter) which are clean of silt, vegetation and algae. Although three of the sites which were initially examined

had good exposure to wave action, they lacked clean substrates. Most rocks at spawning depths were covered with algae (Cladophora sp.) and/or accumulations of silt.

ii) Spawning populations: Nets were initially set at the five most promising locations in October 1984. Two of these sites, #2 off of McCallum Point and #5 just north of Mud Portage, were dropped mid-way through the first sampling season, since trout were not observed or caught in gill nets at these locations. Spawning lake trout had been reported from both areas during previous assessment in the early 1970s (Val Macins, Ministry of Natural Resources, Kenora, pers. comm.). Fish were caught at all other sites throughout the sampling periods in both years.

Lake trout were first observed on the spawning shoals on October 1 in 1984 and October 4, 1985 at surface water temperatures of 12°C. Temperatures rose to 14°C during the 1984 season before falling to 10° towards the end of spawning. In 1985, water temperatures gradually declined to about 9 - 10° where they remained until the completion of the run. The number of fish on the spawning grounds varied nightly but an overall pattern in activity was discernable. The number of fish caught increased to a peak period which lasted 7 - 12 days before dropping off sharply in both years. Although males far outnumbered females in catches, the largest number of ripe females were encountered during these peak periods. Spawning was judged to be over when ripe female trout were no longer present in the nets and the overall number of trout had declined. This was paralleled by an increase in the number of ripe lake whitefish and cisco in the nets during both years. These species spawn later and at cooler water

temperatures than lake trout but are known to utilize the same spawning areas (Scott and Crossman 1973).

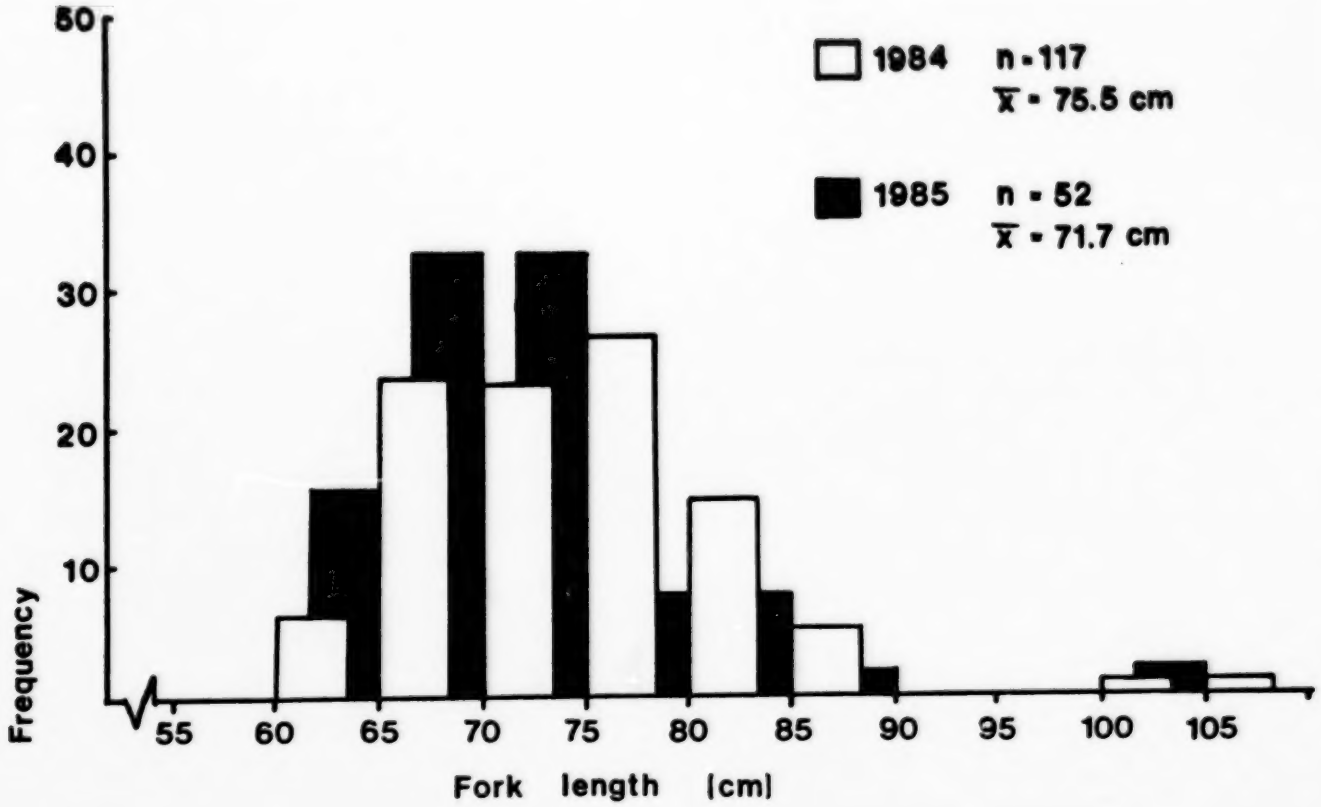
Shoal # 3A accounted for the largest percentage of trout caught during both years (36%), followed by Shoal #1 (28%), Shoal #3B (18%), and Shoal #4 (18%).

No lake trout eggs were found in egg trays which had been placed on Shoals # 1 and 3A prior to the 1985 spawning season and recovered on October 21, 1985. However, eight lake trout eggs were found in the stomach of a mottled sculpin (Cottus bairdi), which was recovered in an egg tray from Shoal # 3A.

iii) Age, size and sex compositions: Over twice as many fish were observed on the spawning grounds in 1984 than in 1985. A total of 117 trout were tagged and released in 1984. Fifty-two trout were caught in 1985 of which 51 were tagged and released, including 9 fish which had lost their disc tags but could still be identified as 1984 recaptures by their scarred right pectoral fin rays. One trout was kept for detailed aging analysis.

Overall, lake trout which were caught on the spawning grounds in 1985 were smaller and younger than those seen in 1984 (Fig. 4). Trout averaged 75.0 cm (F.L.), 5.84 kg in weight, and 10.7 years of age in 1984 as compared to 71.7 cm (F.L.), 4.86 kg in weight, and 8.8 years of age in 1985. These differences were evident for both male and female segments of the catch (Table 3). As commonly reported (Martin and Olver 1980), most female spawners were larger and older than males in both study years.

Both length and age frequency distributions for



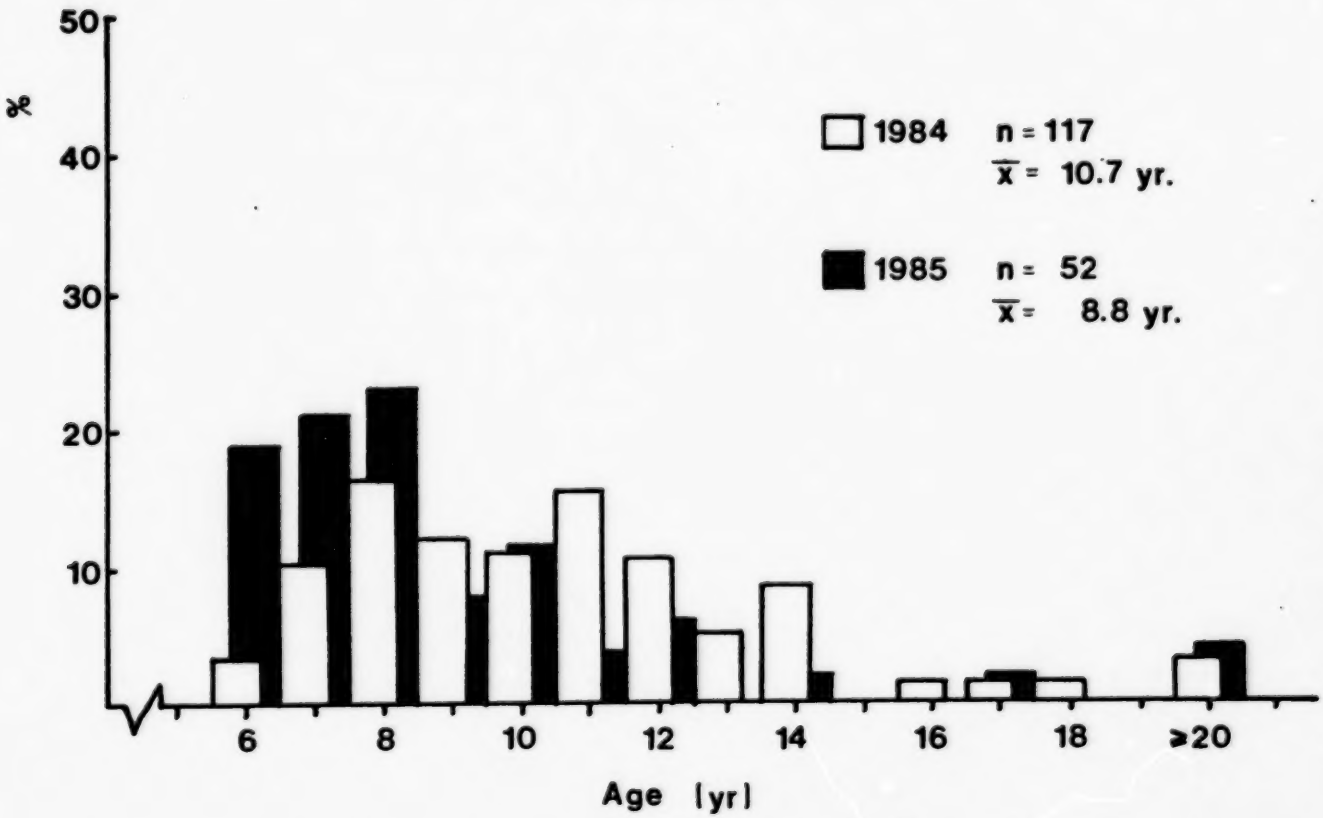


Fig. 4. Comparisons of length-frequency (fork) and age-frequency distributions for lake trout caught in experimental gill nets set on spawning grounds in Clearwater Bay, Lake of the Woods, Ontario, during

Table 3. A comparison of mean fork lengths (cm), weights (kg), and age (yrs.) by sex for lake trout caught on spawning shoals in Clearwater Bay, Lake of the Woods during October 1984 and 1985. The numbers of fish in the samples are given in parenthesis.

		Sampling year	
Attribute	Sex	1984	1985
Fork length (cm)	Male	74.62 (99)	71.56 (40)
	Female	77.10 (18)	74.64 (9)
	All	75.00 (117)	71.70 (52)
Weight (kg)	Male	5.72	4.81
	Female	6.50	5.14
	All	5.84	4.86
Ages (yrs.)	Male	10.65	8.88
	Female	11.00	8.89
	All	10.71	8.83

spawning fish (Fig. 4) indicated a shift to smaller size classes and younger age groups in 1985 when compared to the 1984 sample. The vast majority of fish in both years were between 60 - 80 cm (F.L.) although fish ⩾75 cm comprised a larger percentage of the total sample in 1984 (48.0%) than in 1985 (19.2%). The 1984 age-class distribution tended to be slightly bimodal with strongest representation from age groups 8 and 11 (Fig. 4). The 1985 sample was dominated by fish, 6 - 8 years of age. Over 70% of the fish sampled in 1985 were ⩽9 years old while the majority of those caught in 1984 were ⩾ age 10 (58%).

The largest fish caught during both years were a 17.9 kg trout measuring 107.2 cm (F.L.) in 1984 and a 17.0 kg fish measuring 102 cm (F.L.), in 1985. Both fish were identified as mature males and aged at >27 years old by fin rays.

The ratio of males to females captured on spawning grounds was slightly higher in 1984 than in 1985. Ratios of 5.5 to 1 and 4.4 to 1 were calculated for 1984 and 1985, respectively. All fish caught in 1984 and over 94% of all fish caught in 1985 were mature and could be sexed externally. The youngest and smallest mature fish observed on the spawning grounds were a 61.0 cm male and a 67.0 cm female, both of which were aged at 6 years old.

C) Winter creel survey

Winter creel surveys were conducted on the lake trout fishery of Clearwater Bay during January 1 to March 31 in 1986 and 1987. These surveys provided data on angling effort, harvest, age and size compositions of the catch, angler residency and base of operations. This information could be compared with similar

statistics from the 1982 winter creel survey of this area (Elliott and Brisbane 1982).

Methods: Our surveys concentrated on Clearwater Bay although adjacent areas (ie. Ptarmigan and Echo Bays) were regularly monitored for angling activity (Fig. 2).

The sampling design for 1986 and 1987 surveys differed from the roving creel survey model with non-uniform probability sampling (Malvestuto et al. 1978) which was used in 1982 (Elliott and Brisbane 1982). Both the 1986 and 1987 surveys were based on a model designed to estimate winter effort and harvest on small lake trout lakes in Bancroft and Tweed Districts, Ontario (Loftus 1984). It employs an instantaneous angler count for a specific time period along with observed daily angling activity curves in order to estimate overall angling effort for a specific survey day.

During all survey years, an angling day was considered to be the 10 hour period from 08:00 to 18:00 hours. Workdays were stratified from non-workdays which included Saturdays, Sundays and statutory holidays. The angling day was divided into five sampling periods of two hours each (08:00 - 10:00; 10:00 - 12:00, etc.). Only one time period per day was sampled and was usually scheduled for sometime during the hours of greatest daily angling activity (11:00 -16:00 hours, Appendix 2). Daily angler activity curves were generated for both workdays and non-workdays. These resulted from instantaneous counts of all anglers within the Clearwater Bay survey area during the mid-point of each 2 hour time period throughout specific sampling days in 1982, 1986, and 1987. At least 5 days per day-type were sampled in this manner and a distribution of the relative abundance of anglers present during different time periods by day-type resulted (Appendix 2). These average values for relative angler abundance were used to calculate an

expansion factor (F) by the following:

$$F = (2) \cdot (100/P_t)$$

where P_t = percentage of the daily fishing effort expected to occur in time period "t".

The length of each time period was 2 hours in this case. Thus, an instantaneous angler count for a specific time period on a particular survey day could be expanded to obtain an estimate of total angling effort for that day.

At least one workday and one non-workday were sampled each week during the survey period. The limited size of the Clearwater Bay area permitted complete survey coverage during a single sampling period. An instantaneous count of all anglers present on the lake was made by truck and/or snowmachine near the mid-point of each survey period. Interviews were conducted with all fishing parties seen. Information concerning angler residency, fishing methods and success, and the estimated trip length were recorded. All lake trout retained by anglers were weighed, measured and examined for tags and/or marks. With the angler's permission, sex organs and stomach contents of trout were examined. Lake trout otoliths, scales, and marginal pectoral fin rays were removed for aging purposes. Lake trout otoliths were prepared for age interpretation using the acetate replicate method (Panella, 1980; Brothers, 1987).

Estimates of angling effort and harvest were calculated for an early (January 1 - 24), mid (January 25 - February 28), and late winter (March 1 - 31) season in each survey year. Since most anglers who were contacted during both survey years fished with only one line apiece, effort and catch-per-unit effort estimates were expressed in terms of man-hours as opposed to rod-hours.

An observed catch-per-unit-effort was calculated for

each survey day and applied to the estimated daily effort to obtain a daily harvest. An average daily harvest value for an appropriate day-type and season was calculated. These were expanded to obtain harvest estimates for each season and the entire survey period.

The precision of estimates was expressed as an interval at the 95% confidence level (Steel and Torrie 1980).

Results and Discussion:

i) Effort: A total of 360 and 549 anglers were contacted from January 1 to March 31 in 1986 and 1987, respectively.
Angling effort had increased dramatically in this area between 1982 and 1987 (Fig. 5). Total angling effort for the survey period was estimated at 10,048 man-hours ± 6678.8 (at 95% confidence level) in 1986 and 15,502 man-hours ± 9309.4 in 1987. Elliott and Brisbane (1982) estimated total fishing effort for the same period in 1982 at 4,314 man-hours ± 2,829.9.

Effort was greatest during the first few weeks of January following the opening of the trout season in both survey years (January 1) and declined seasonally to its lowest levels in March (Table 4). Greater effort was expended on non-workdays than on workdays in all months sampled.

Both solid ice and limited snow accumulations provided for good travel conditions to fishing locations on the lake throughout the winter in all survey years.

Some angling activity was observed on both Cul de Sac and Echo Bays during our surveys. Since overall effort in these areas was minimal when compared to the Clearwater Bay fishery, the results are not reported.

ii) Harvest: Lake trout remained the target species of

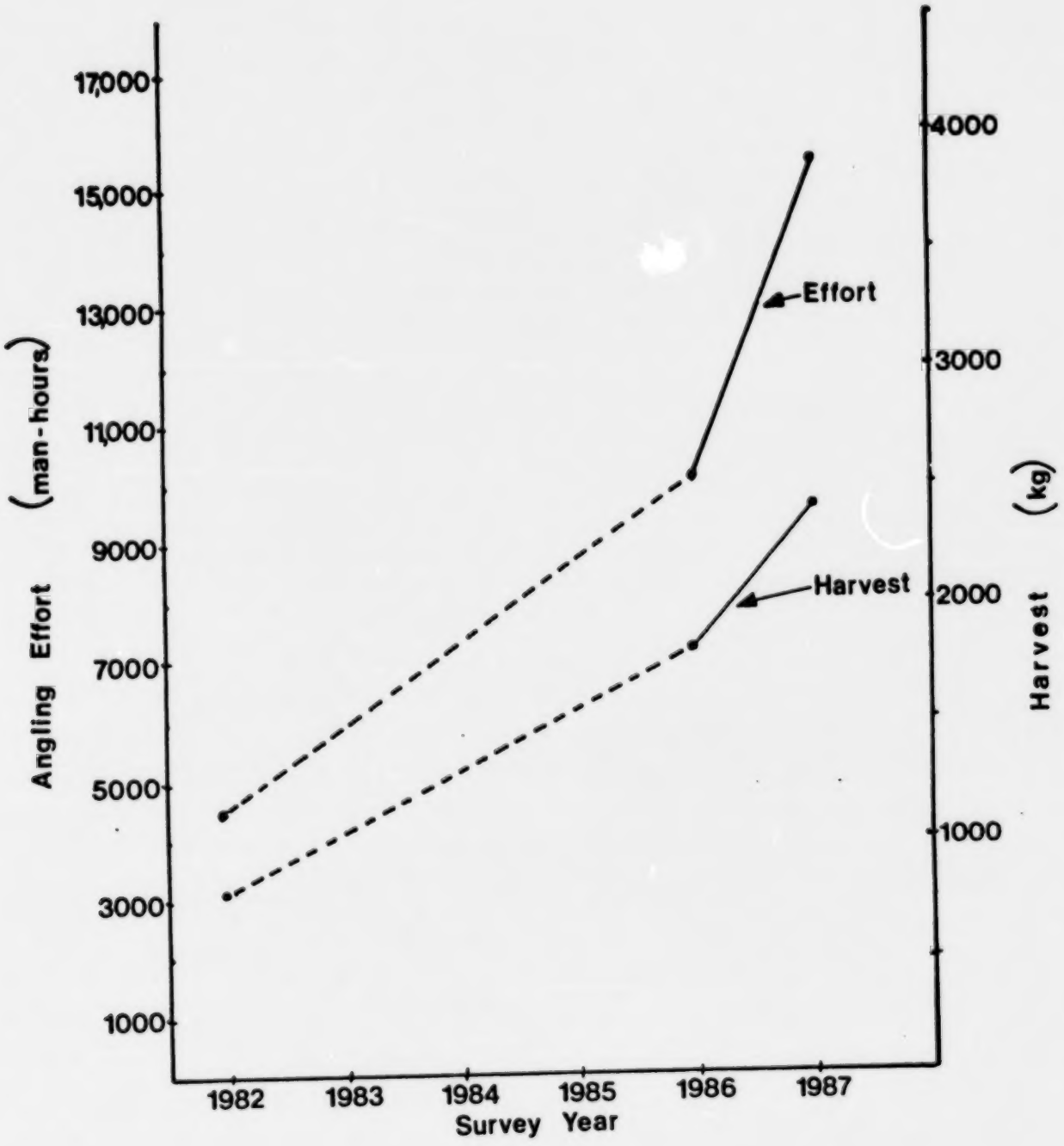


Fig. 5. A comparison of effort (man-hours) and harvest (kg) of lake trout by the winter angling fishery on Clearwater Bay, Lake of the Woods during January 1 - March 31 in 1982, 1986 and 1987.

Table 4. A comparison of estimated angling effort (man-hours) and harvest (kg) of lake trout on Clearwater Bay, Lake of the Woods during January - March in 1982, 1986, and 1987.

Year	Period	Estimated effort (man-hours)	Estimated harvest (kg)
1982	January (1-31)	1,643.7	503.7
	February (1-28)	1,971.7	229.7
	March (1-31)	699.0	59.4
	Total	4,314.4 ±2,829.9*	792.8 ±855.6*
1986	January (1-24)	7,370.4	1,491.0
	January 25 - February 28	2,337.3	290.9
	March (1-31)	341.0	12.5
	Total	10,048.7 ±6,678.8	1,794.4 ±2,059.8
1987	January (1-24)	10,831.7	2,173.8
	January 25 - February 28	3,234.7	124.0
	March (1-31)	1,435.6	105.1
	Total	15,502.0 ±9,309.4	2,402.9 ±2,630.7

* ± values represent the 95% confidence interval.

anglers on Clearwater Bay during winter surveys. Total lake trout harvest was estimated at 1794.4 kg and 553 fish in 1986, and 2402.9 kg and 803 fish in 1987 (Fig. 5). Winter harvests increased by 126% and 203%, respectively, over the estimated harvest of 793.0 kg and 195 trout for the same period in 1982 (Elliott and Brisbane 1982). Current harvests represent lake trout yields of 0.78 and 1.04 $kg \cdot ha^{-1} \cdot yr^{-1}$ during 1986 and 1987.

Most of the estimated harvest occurred at the beginning of the lake trout season and the survey period. Anglers had taken over 83% and 90.5% of the total estimated trout harvest in 1986 and 1987, respectively, by the third week of January (Table 4). Estimated harvests declined to their lowest levels in March.

iii) Catch-per-unit-effort (CUE): Catch-per-unit-efforts for lake trout (both kg and number of fish caught per man-hour) were calculated from the observed catch.

Catch-per-unit-efforts by weight have declined from 0.152 kg per man-hour in 1982 (Elliott and Brisbane 1982) to 0.132 and 0.125 kg per man-hour during 1986 and 1987, respectively (Fig. 6). The CUE, expressed as number of fish per man-hour, increased from 0.033 in 1982 to 0.046 in 1986 and 0.042 fish per man-hour in 1987.

Fishing success for lake trout, as expressed by CUE, would appear to be greatest early in the season during the first few weeks of January. The highest daily catch-per-unit-efforts (0.366 to 0.436 kg per man-hour) were observed during the first week of January in both study years. Although considerable variation in daily CUE occurred throughout the season, the general trend was to decreased angling success during February and March. A similar pattern was observed during the 1982

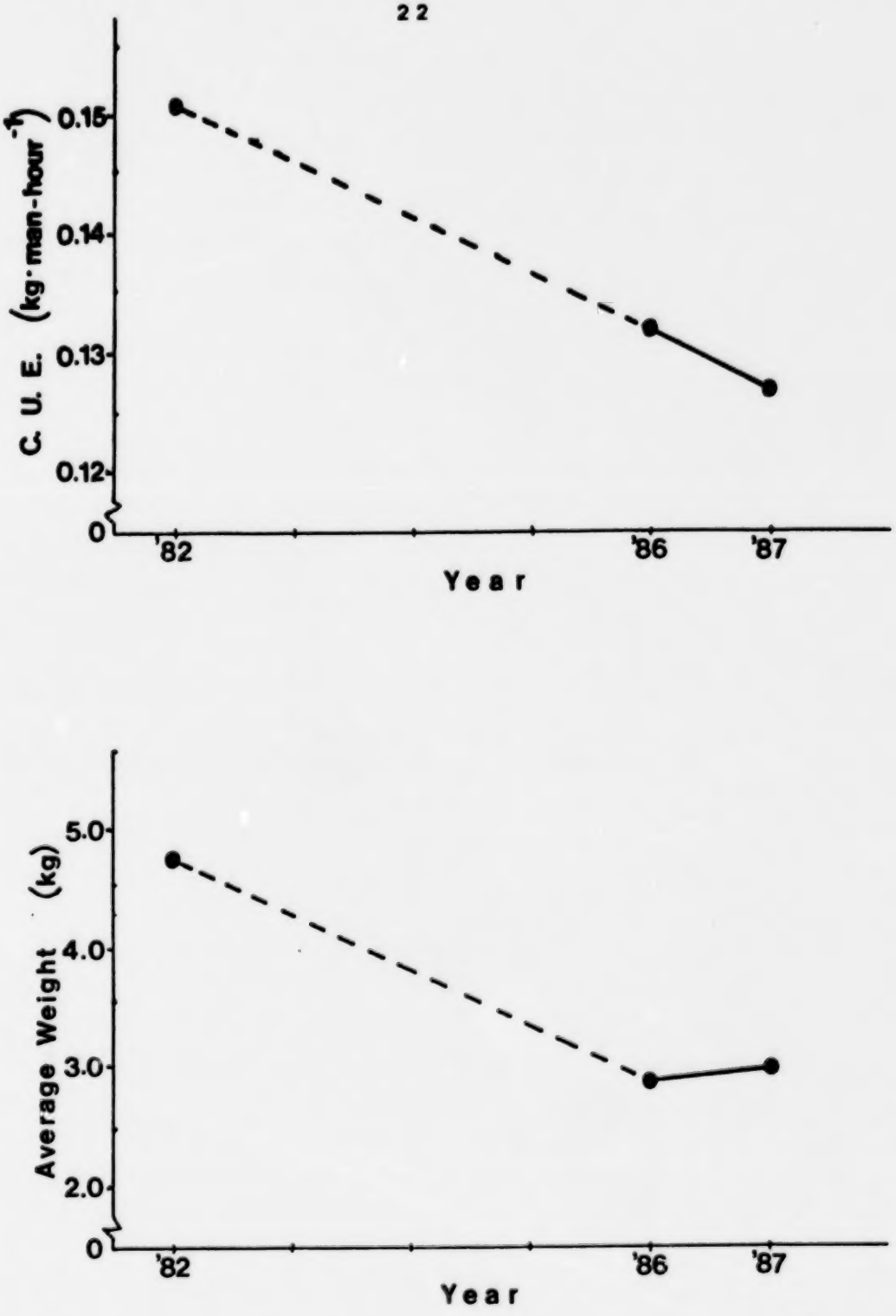


Fig. 6. A comparison of catch-per-unit-efforts (kg·man-hour^{-1}) and average weight (kg) of lake trout caught by anglers in Clearwater Bay, Lake of the Woods, during January 1 - March 31 in 1982, 1986, and 1987.

winter survey (Elliott and Brisbane 1982).

iv) Age and size compositions of the catch: Both the mean age and size of lake trout caught by anglers in 1986 and 1987 (Figures 7, 8 and 9) had declined when compared to the 1982 catch (Elliot and Brisbane 1982).

The size compositions of the sampled catch in 1986 and 1987 were similar (Fig. 7 and 8). Fish averaged 2.76 kg in weight and 57.4 cm (F.L.) in 1986, and 2.98 kg in weight and 57.6 cm (F.L.) in 1987. Mean weights and lengths were significantly smaller (Student T-test, $p<0.05$) than those observed in 1982 ($\bar{x}$ = 5.01 kg and 70.7 cm fork length).

Although a limited number of fish were aged from otoliths, these indicated that the mean age of the catch had also decreased, from 9.8 years in 1982 to 7.7 years during 1986 and 1987 (Fig. 9).

Both age and size compositions of the 1986 and 1987 catch samples had shifted to younger age and smaller size classes than those observed in 1982. Lake trout, less than 60 cm (F.L.) and 9 years of age, represented about 80% of observed age compositions and 65% of length compositions in both years. In 1982, these same age and size classes comprised 15.2% and 29.6% of observed age and size distributions, respectively.

An angling catch sample of 36 trout in 1982 and 41 trout in 1987 were examined for sex and state of maturity. Fish which were identified as immature or maturing (ie. they had not yet spawned for the first time) comprised 25% of the sample in 1982 and 71% of all fish sampled in 1987. Mature fish represented 75% and 29% of fish sampled in 1982 and 1987, respectively.

v) Residency of anglers: There has been a substantial increase in the participation of anglers who are non-

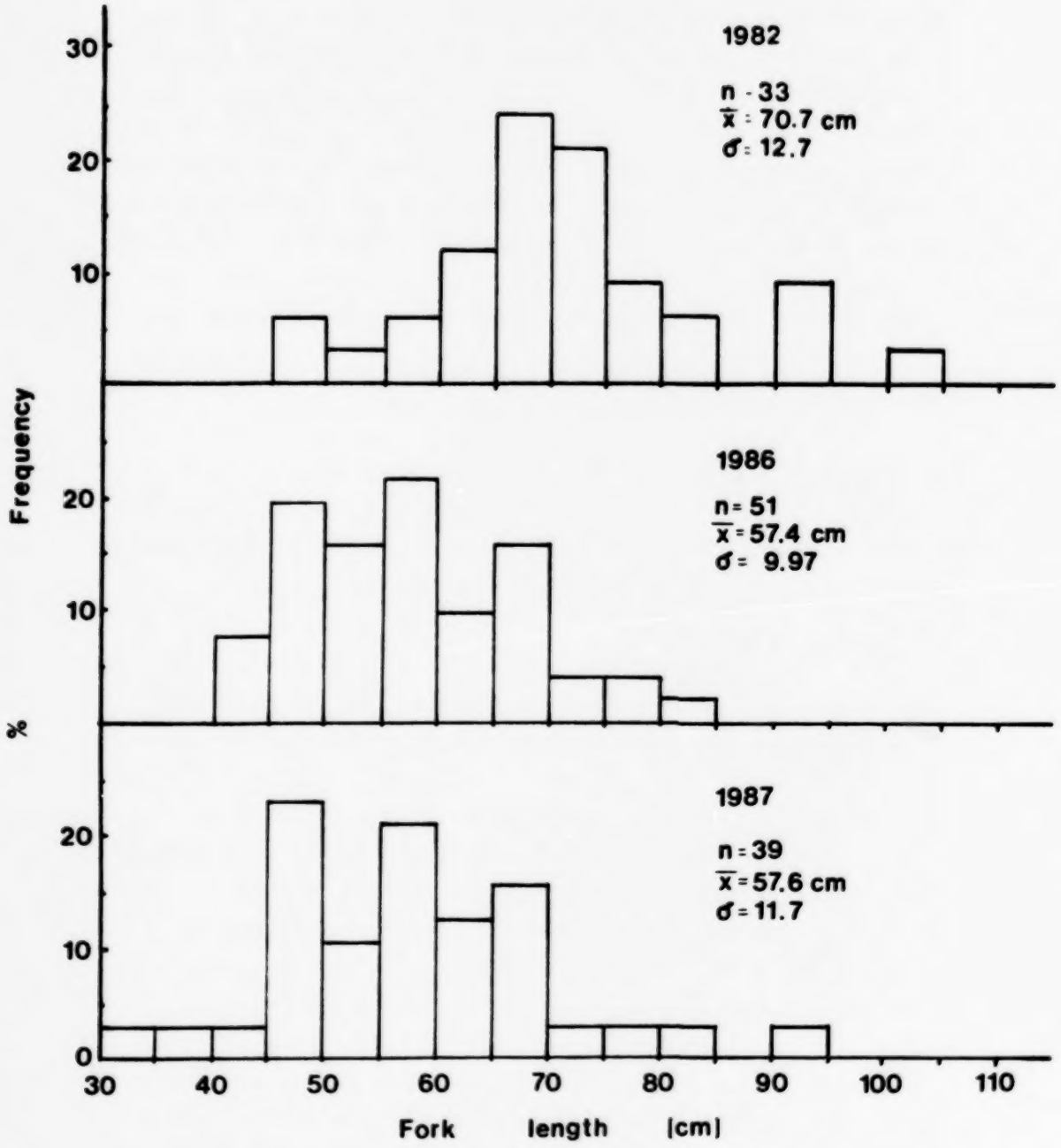


Fig. 7. Length-frequency distributions for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986, and 1987 from Clearwater Bay, Lake of the Woods, Ontario.

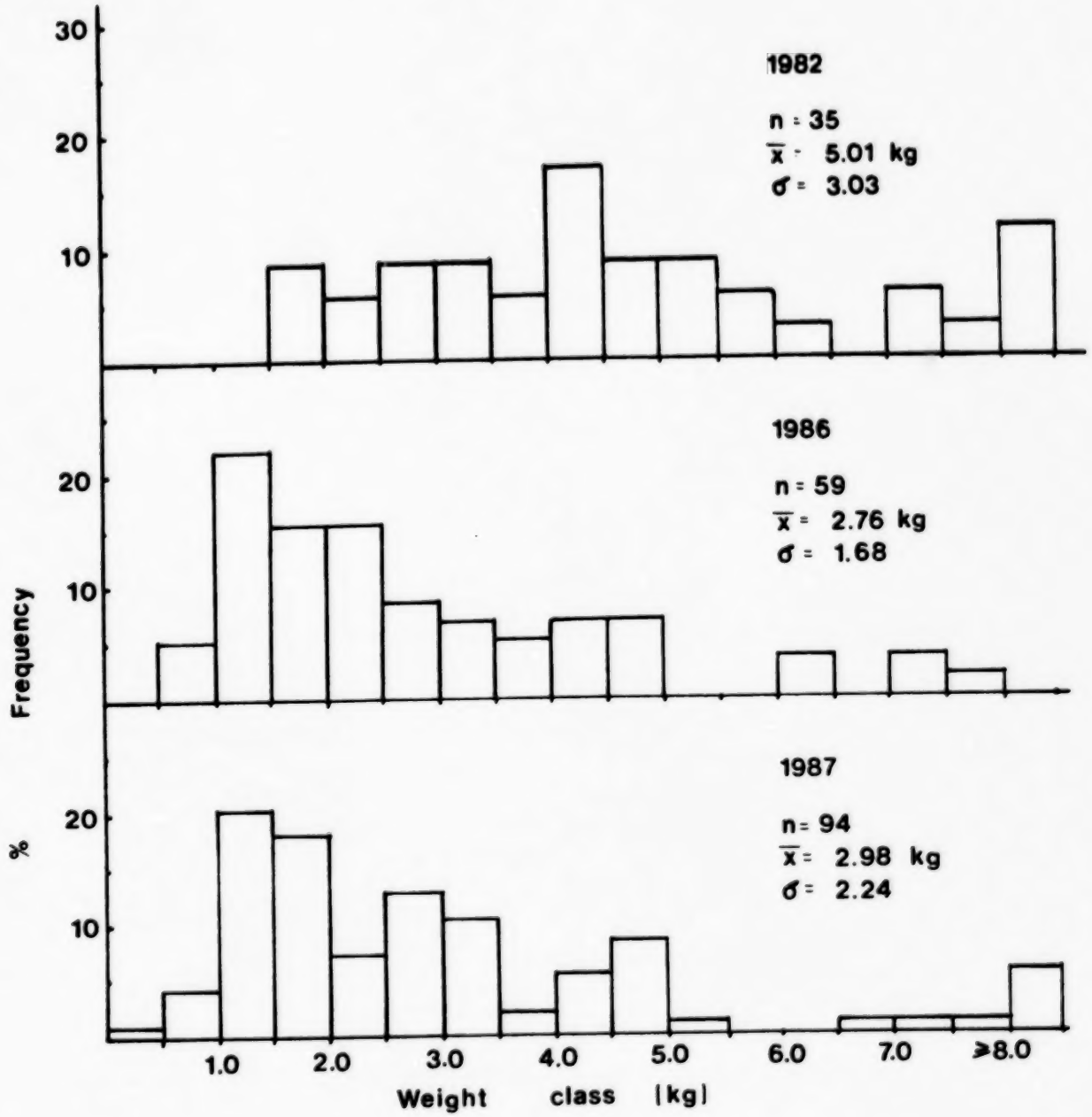


Fig. 8. Weight class distributions (kg) for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986 and 1987 from Clearwater Bay, Lake of the Woods, Ontario.

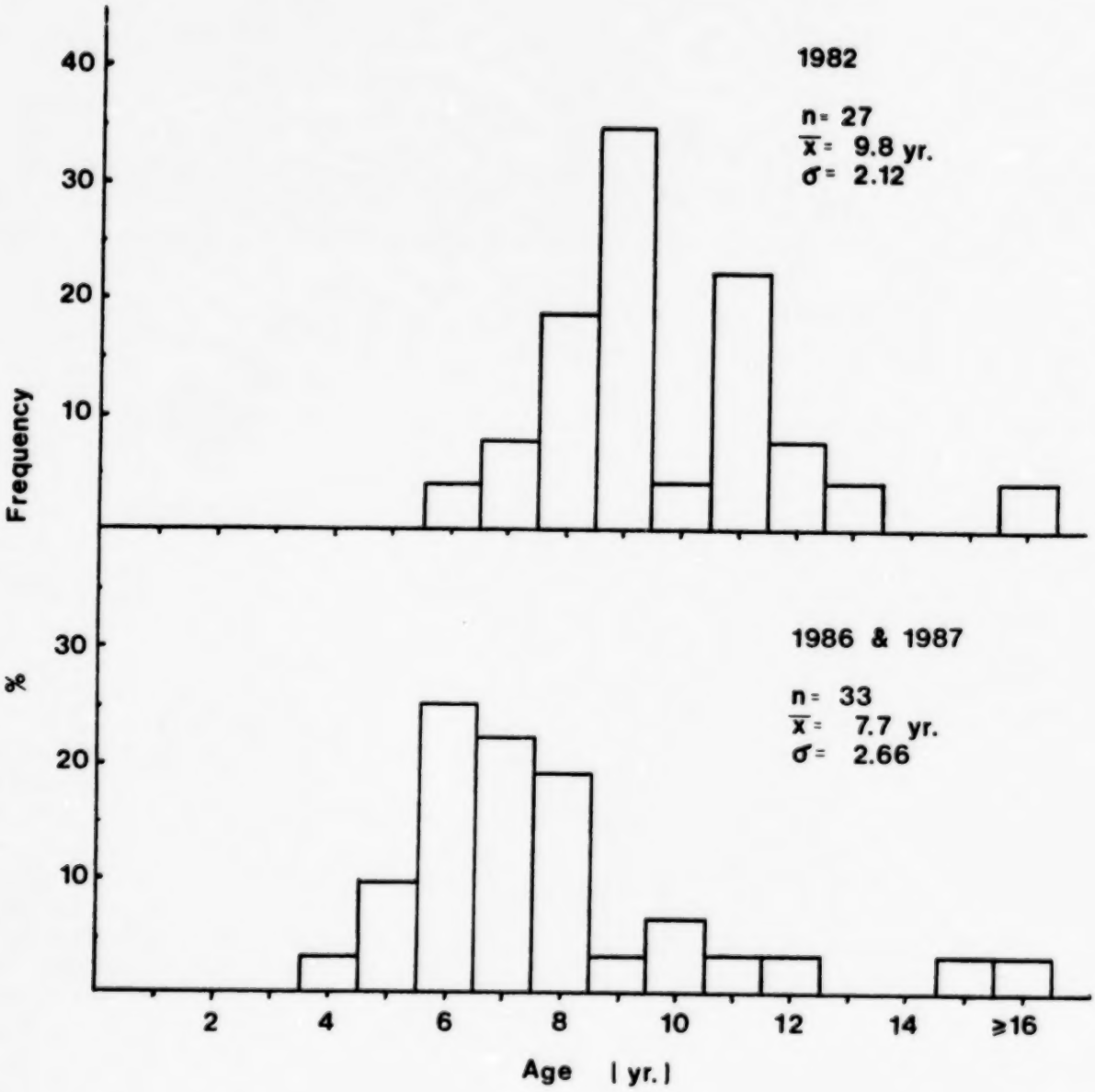


Fig. 9. A comparison of age-frequency distributions (based on otolith age interpretations) for lake trout sampled from the angling catch during January 1 - March 31 in 1982, 1986 and 1987 from Clearwater Bay, Lake of the Woods, Ontario.

residents of Ontario in the Clearwater Bay winter fishery since 1982 (Fig. 10). Local residents, from Kenora - Keewatin comprised over 79% of all anglers interviewed in 1982. The remainder were mostly non-residents from Manitoba. By 1987, local Ontario residents represented 46.4% of all anglers while Manitoba anglers had increased to 34.8% of the total. American fishermen, primarily from Minnesota, comprised 18.8% of all anglers contacted.

The 1987 creel survey also indicated that anglers were being attracted from further afield to the Clearwater Bay winter fishery. Several parties which were interviewed had travelled 400 - 500 km, from as far away as Bemidji, Minnesota and Thunder Bay, Ontario, specifically to fish on Clearwater Bay.

iv) Tag returns: A total of 11 lake trout which could be identified as being previously marked during fall spawning assessment in 1984 and 1985 were caught by the angling fishery during 1984 - 87.

All recoveries were made in Clearwater Bay near the vicinity of tagging locations. The furthest tag recovery (11 km) was from a trout which had been tagged in Deception Bay in October 1985 and caught by an angler near Kendall Inlet, at the extreme east end of Clearwater Bay, in March 1986 (Fig. 2). The majority of tagged fish were caught by winter anglers although two trout were taken during the open water season.

Although nearly twice as many trout were tagged in the fall of 1984, most tag recoveries were from the 1985 tagging program. Only 4 out of a total of 117 fish tagged in 1984 were identified from the angling catch. Seven recaptures originated from the 1985 season when 51 trout were tagged and released. We suspect an unusually high rate of tag loss from fish handled in 1984. All 1984 recaptures which were caught on

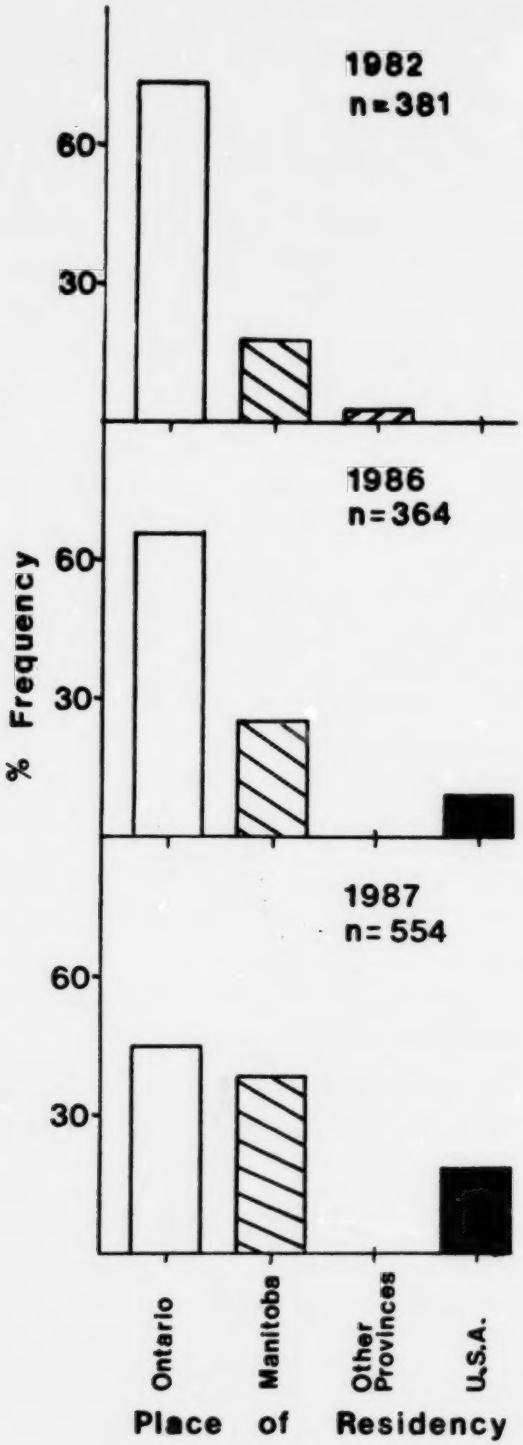


Fig. 10. Residency of anglers contacted on Clearwater Bay, Lake of the Woods, during January 1 - March 31, in 1982, 1986, and 1987.

spawning grounds in 1985 had lost their tags. It would appear that disc tags which were sewn into the outer margin of the opercular flap of trout in 1984 were more easily lost than those used in 1985. Tags were affixed just anterior to the dorsal fin in 1985.

Estimates of an exploitation rate, based on tag returns from the angling fishery, were complicated by two sources of systematic error (Ricker 1975). These were identified as: 1) the loss of tags from fish shortly after marking and; 2) the incomplete reporting of marks or tags taken by fishermen. These errors not only affected the return of 1984 tags but probably 1985 tags, as well. This is supported by the fact that a greater number of 1985 tags were returned from fish caught in 1987 than in 1986. Therefore, an exploitation rate of 5.9%, based on angler tag returns during the first year (i.e. 1986) following tagging in the fall of 1985, should be viewed as an underestimate.

D) Growth and maturity regimes

Rates of growth and maturity were calculated for Clearwater Bay lake trout based on fish sampled from the 1982, 1986 and 1987 angling creels, and from the 1984 and 1985 North Sector index netting programs.

Methods: The vast majority of samples were obtained from the winter angling catch. Besides length and weight measurements, otoliths along with pectoral marginal fin ray and scales were sampled from each fish. Otoliths and fin rays were prepared and aged using standard procedures. Because we encountered difficulties in determining whether lake trout sampled during the winter were immature or maturing (i.e. they had not spawned for the first time), fish were identified by sex and their state of maturity was classed as either immature/maturing or mature. Sample sizes for the calculation of growth and maturity

regimes were small and were limited only to those fish from which otoliths were obtained.

Results and Discussion

i) Aging analysis: Ages interpreted from fin rays were significantly younger ($p < 0.05$, student T test) than those determined from otoliths in a comparison of these two aging structures from the same fish. Age interpretations from fin rays consistently underestimated ages for all size ranges ($\geq$30 cm F.L.) of Clearwater Bay trout which were examined (Fig. 11). Comparisons of fin ray with otolith ages for walleye (Erickson 1981) and lake trout (Swainson 1985) have indicated good agreement up until maturity. Swainson (1985) found that only otoliths seemed to provide good estimates of age for large trout greater than 45 cm (F.L.) from Lake Opeongo, Ontario.

Annuli (annual growth checks) were more easily distinguished on lake trout otoliths than on fin ray sections in the present study, especially in the case of older fish where growth was slower and annuli tended to be more closely spaced towards the outer margins of the structure.

ii) Growth: Growth relationships were not separated by sex since sample sizes were limited. Growth of lake trout in Clearwater Bay, based on otolith ages, was rapid. The growth rate, expressed as mean length-at-age (Fig. 12), was considerably greater than the provincial average for this species which was calculated from scale ages (Ont. Min. Natural Resources 1983). As commonly reported (Scott and Crossman 1973; Martin and Olver 1980), growth in length decreased while growth in weight increased following maturity (Table 5).

The rapid growth of Clearwater Bay trout probably

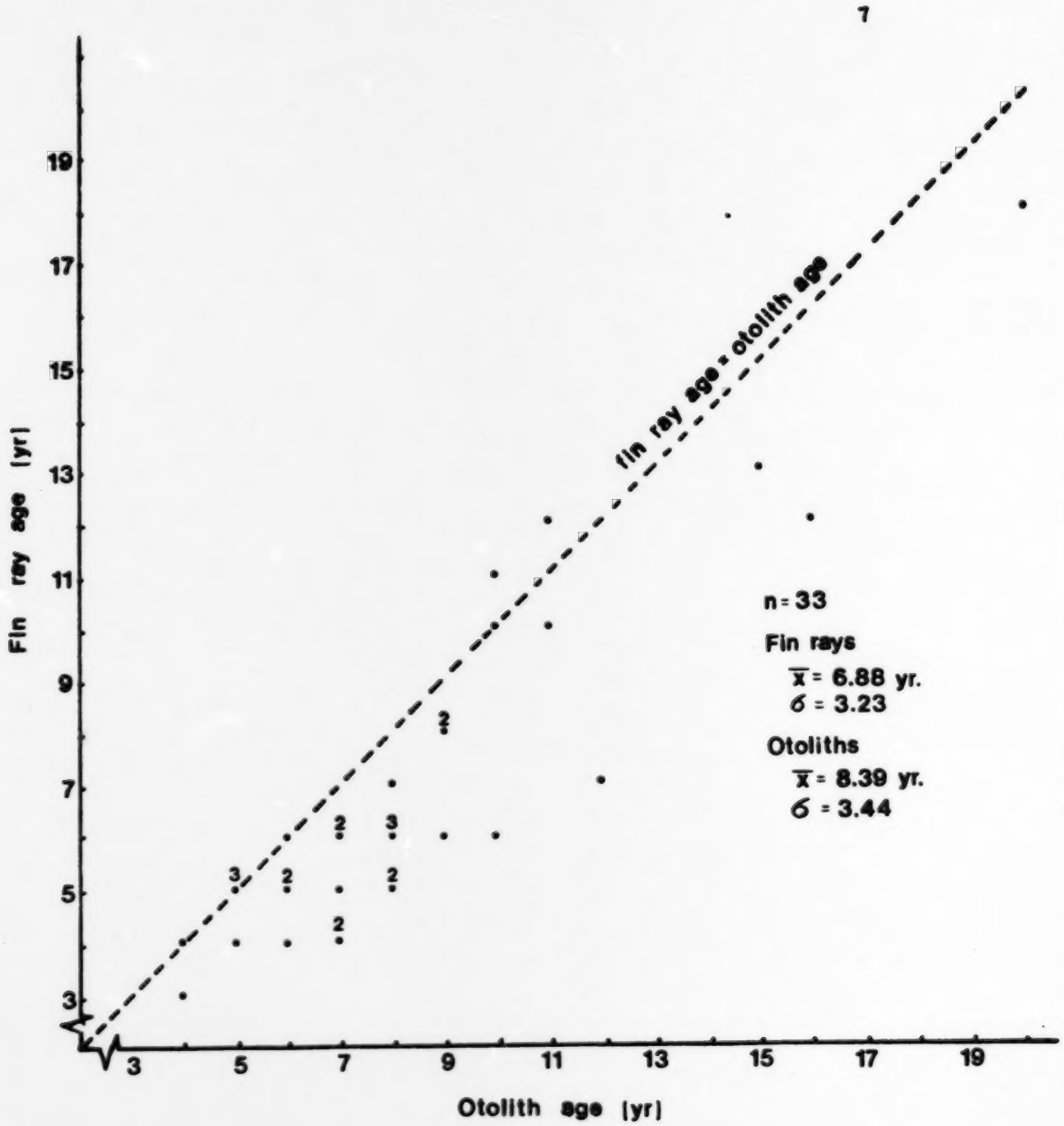


Fig. 11. A comparison of ages interpreted from pectoral fin rays vs. otoliths from lake trout caught in Clearwater Bay, Lake of the Woods during 1984-87. Numbers indicate sample sizes.

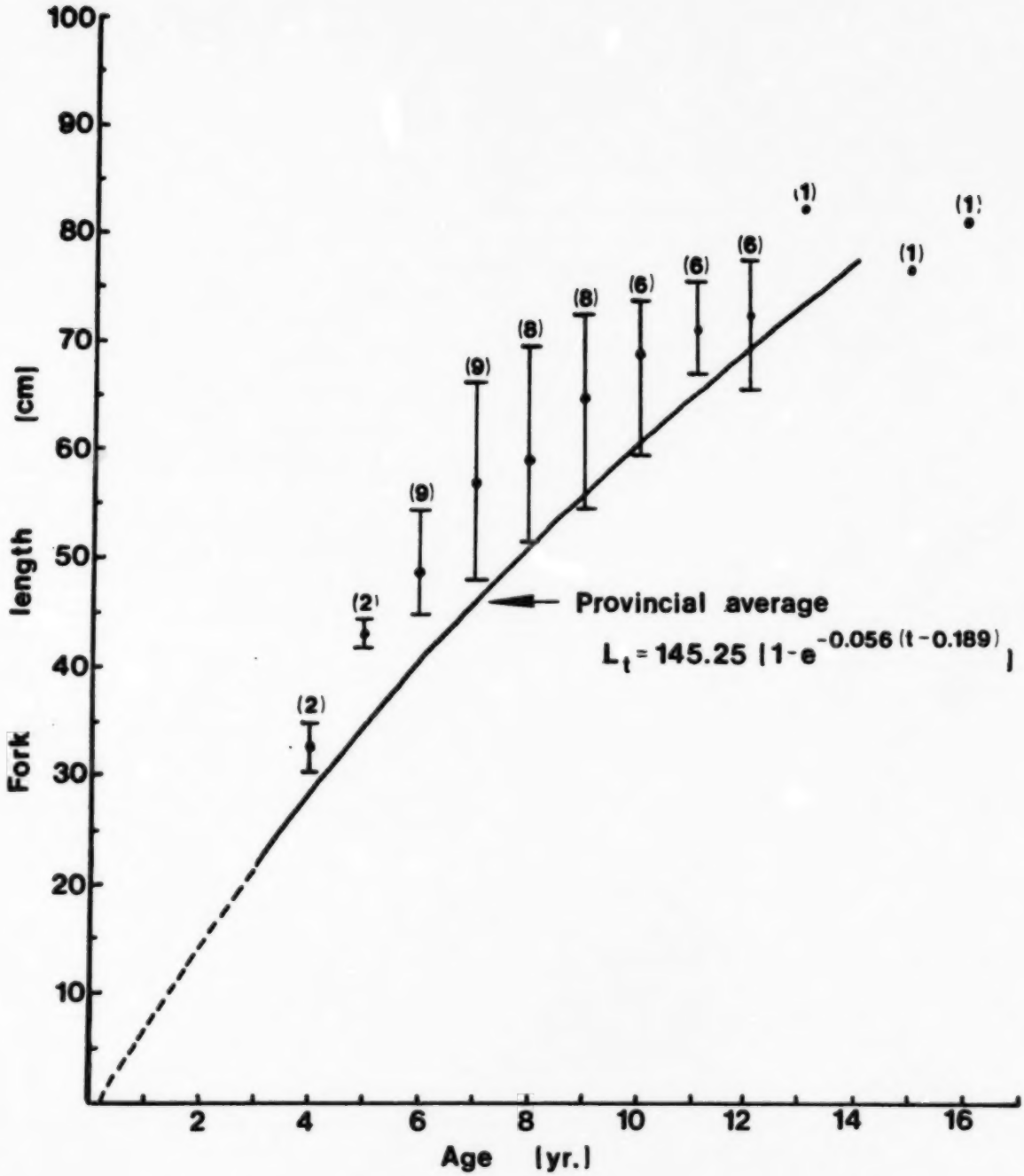


Fig. 12. A comparison of mean fork lengths-at-age for Clearwater Bay lake trout with the provincial growth averages for this species (OMNR 1983). Ages for Clearwater Bay trout were assessed from otoliths while the provincial averages were derived from scale interpretations. Numbers indicate the sample sizes used in calculation. Horizontal bars represent the minimum and maximum lengths of fish observed in each age-class.

Table 5. Mean fork length (cm), mean weight (kg), and state of maturity by age (based on otoliths) of lake trout sampled from winter angling and index netting catches from Clearwater Bay, Lake of the Woods, Ontario, 1984 - 87.

Age (yr)	No. sampled	Mean length (cm)	Mean weight (kg)	State of Maturity				
				No. sampled	Male		Female	
					Immature /Maturing	Mature	Immature /Maturing	Mature
4	2	32.5	0.35	2	1	0	1	0
5	3	42.5	0.84	3	2	0	1	0
6	9	48.8	1.38	9	3	1	4	1
7	9	56.5	2.10	7	2	1	1	3
8	8	59.2	2.46	5	0	2	1	2
9	8	64.6	3.38	5	0	2	1	2
10	6	68.5	3.90	2	0	1	0	1
11	6	70.2	4.74	2	0	2	-	-
12	6	71.9	5.10	4	0	4	-	-
13	1	82.5	7.40	-	-	-	-	-
14	-	-	-	-	-	-	-	-
15	1	76.0	7.00	1	0	1	-	-
16	1	81.0	7.70	1	0	1	-	-
21	1	84.6	7.50	1	0	1	-	-

reflects the higher productivity of this area than is typical of most lake trout waters. Increased angling pressure since 1980 would serve to further stimulate lake trout growth rates as a result of reductions in stock density (Healey 1978).

iii) **Maturity regimes**: A limited number of lake trout (n=42) were examined internally for their state of maturity (Table 5). All sampled trout, 5 years or younger, were immature. The youngest mature male and female fish examined were 6 years of age, and measured 54.8 cm and 56.0 cm (F.L.), respectively. All males $\geq$8 years old were mature while some females had not yet matured by age 9.

The ages at first maturity for Clearwater Bay trout would appear to fall within the reported range for Ontario lakes of 4 - 7 years old for males and 4 - 8 years for females (Martin and Olver 1980).

Management Implications

The lake trout population in Clearwater Bay clearly exhibits signs of stress from overexploitation by the angling fishery. A decline in water quality and continuing shoreline development are also suspect in the gradual loss of spawning areas and summer habitat for this species. These forces, if left unchecked, will likely result in the loss of a naturally reproducing lake trout population from this area.

i) Habitat: Although the extent of changes in water quality are difficult to assess without comparable background information, the results of the 1984 study suggest that an increase in nutrient status to levels which are atypical of oligotrophic, lake trout waters has occurred. Total phosphorus concentrations were well above the range of values for nutrient poor, oligotrophic lakes and were more indicative of meso-eutrophic lake productivity (Wetzel 1975). While chlorophyll a levels were slightly higher than is typical of lake trout waters, they were lower than might be expected, in view of the observed total phosphorus concentrations. Chlorophyll a concentrations are probably limited by the shorter growing season, experienced by this area, when compared to more southerly regions in Ontario. (D. Hollinger, Ministry of the Environment, Thunder Bay, pers. comm.).

Higher productivity, especially as a result of increased phosphorus levels, would account for increased phytoplankton activity in the upper water layers and greater production of organic matter which is the primary source of sediments in the bottom depths below the thermocline (hypolimnion). Greater organic sedimentation is directly related to increased depletion of hypolimnetic oxygen, since oxygen is consumed during bacterial decomposition of these organic sediments (Wetzel 1975). Reductions in hypolimnetic oxygen during late summer which were observed at all stations, especially Clearwater Bay - East,

affected a greater volume of the hypolimnion than would be expected in more oligotrophic waters. Although a large capacity of optimal lake trout habitat remains in the hypolimnion, owing to the great depth of these basins, increases in productivity will act to further restrict summer lake trout habitat in the future.

Increases in productivity can also be expected to further stimulate algal growth on shallow water substrates and reduce suitable lake trout spawning habitat. We observed a dense cover of algae (primarily Cladophora sp.) along most rocky shorelines of Clearwater Bay during mid to late summer. Extensive cottage developments around most of the bay have increased erosion and resulted in siltation of shorelines at several locations. The number of areas with clean substrates required by lake trout for spawning were limited. No spawning activity was observed on several shoals where trout had previously spawned in the early 1970s but increased algae and silt deposits were now present.

Inputs of nutrient from external sources are probably responsible for the elevated productivity of Clearwater - Echo Bays since these basins are located on an area of the Precambrian Shield which is characteristically poor in carbonates or calcareous material. These bays are also isolated from major currents and exchanges with the rest of Lake of the Woods. Wastewater and septic field leachates from cottages surrounding Clearwater and Echo Bays are the most likely sources of external nutrient into these basins. This area has experienced a long history of intensive recreational and cottaging use, going back to the late 1930s, but it was not until 1973 that existing restrictions on the disposal of sewage and wastewater were enforced (John Barr, Ministry of the Environment, Kenora, pers. comm.). While current regulations require the installation of approved septic fields at all new developments, land adjacent to these bays is composed mostly of bare rock with thin soils which are not conducive to either the construction or proper operation

of those facilities.

A concentrated effort to control if not reduce external inputs of nutrient into Clearwater and Echo Bays are required. Restrictions on further cottage and shoreline development, and assessment to determine the effectiveness of existing septic facilities would be positive steps to insuring that spawning and summer habitat for lake trout continue to exist in this area.

ii) **Harvest**: The impact of angling on lake trout populations in Clearwater Bay is much more clearly defined. Although Clearwater had always experienced some angling pressure during open water and had even been commercially fished as recently as the 1950s, it was not until the late 1970s that local anglers "discovered" the vulnerability of lake trout in this area to winter fishing and exploitation began in earnest. Both the easy accessibility of this location, directly off of the Trans-Canada highway, and its potential for producing large "trophy sized" lake trout in excess of 10 - 15 kg were important factors in the popularity of this fishery from the start. Between 1982 and 1987, estimated winter harvest and effort tripled from about 800 kg and 4300 man-hours in the winter of 1982 to 2400 kg and 15,500 man-hours of angling in 1987. Interviews with anglers have shown that an increasingly larger percentage are non-residents from Manitoba and the United States. These groups now make up more than half of all winter anglers. They have been drawn to this location specifically by its reputation as a trophy lake trout producing area.

The dramatic expansion of this fishery has been paralleled by a steady decline in the catch-per-unit-effort (weight) and significant decreases in the mean size and age of trout in the harvest. The percentage of mature fish in the catch has decreased from 75% in 1982 to less than 30% of the observed harvest in 1987. This provides further evidence that anglers have substantially reduced the abundance of large fish in this

area and are now in the process of "fishing down" this population. Angling has already begun to limit future brood stock numbers and the reproductive potential of this population through increased fishing mortality on younger age groups. Recent winter harvests of 1800 kg in 1986 and 2400 kg in 1987 represent overharvests of 57% and 109% above a calculated allowable yield of 1150 kg.yr^{-1} for Clearwater Bay (2300 ha surface area), given a suggested sustainable yield of 0.5 kg·ha^{-1}·yr^{-1} for this species (Healey 1978).

While large "trophy sized" trout are still taken in Clearwater Bay and the average size of fish caught remains higher than in most district or provincial lakes, the quality of this fishery has declined and will continue to do so unless corrective measures are taken. Although lake trout growth in Clearwater Bay is extremely rapid, it still requires a minimum of 15-20 years to produce a trophy sized trout(>7kg).

Tighter controls are required to reduce annual harvests, to at least the recommended allowable yield level. Efforts to provide greater protection for brood stock should remain a primary consideration, given the relatively small size of spawning populations and the limited number of remaining spawning shoals in Clearwater Bay. The reduction of annual harvests to well below the allowable yield may be required to maintain trophy angling opportunities.

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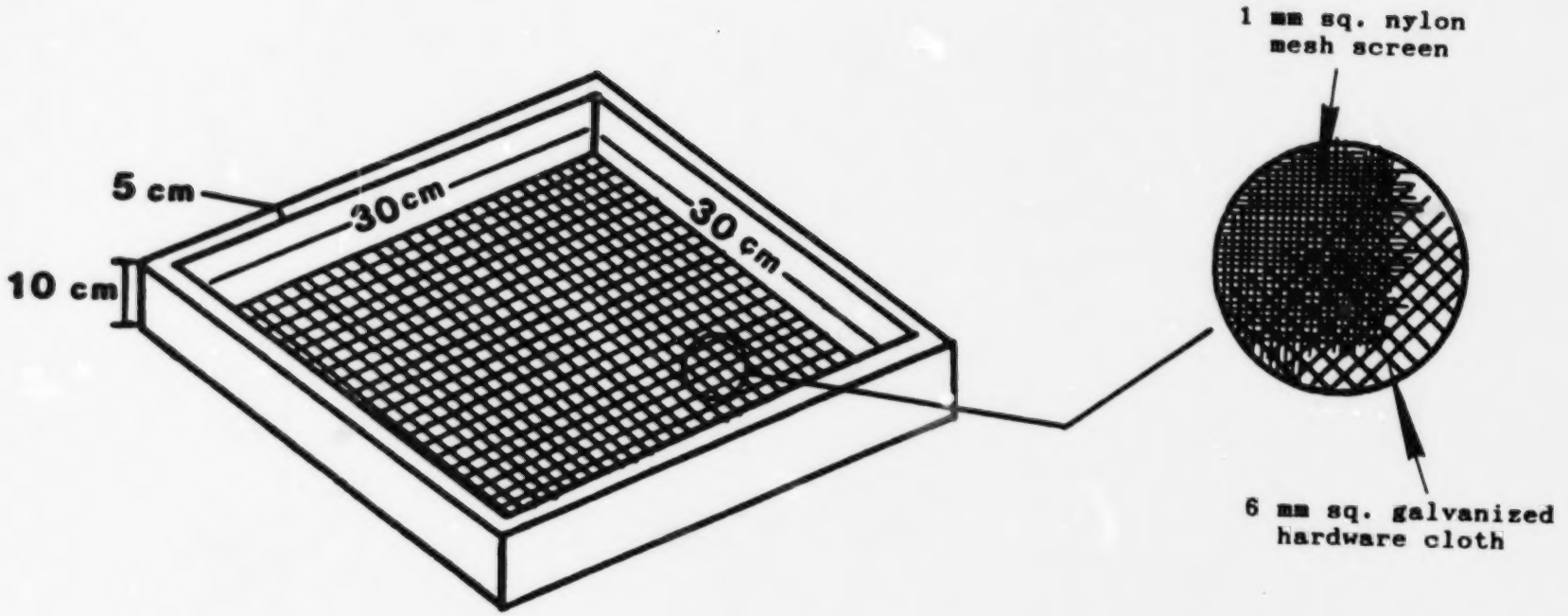
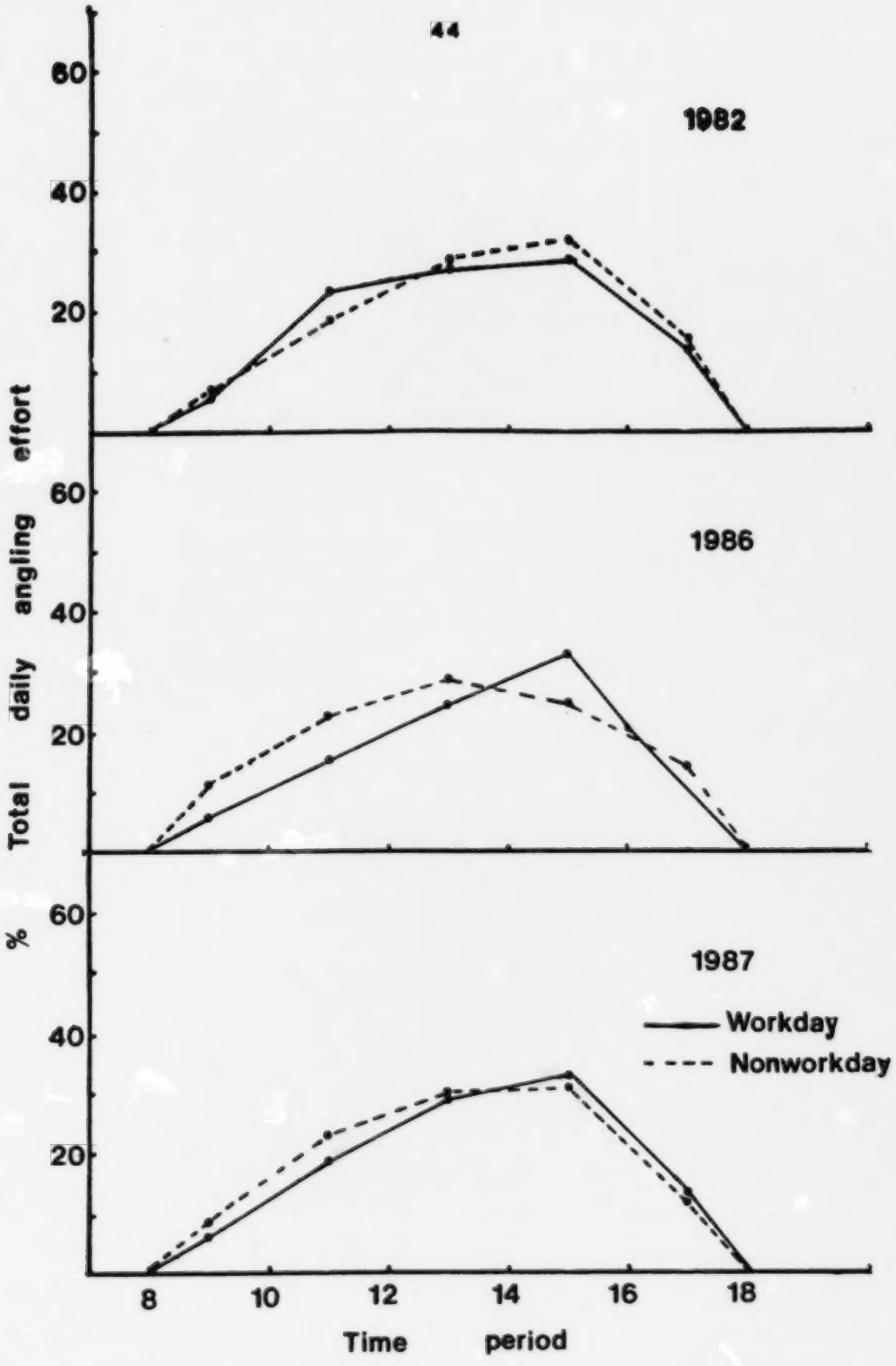


Appendix 1. Diagram of an egg deposition tray.



Appendix 2. Angling activity curves for both non-workdays and workdays from Clearwater Bay, Lake of the Woods during January - March in 1982 and 1987.